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THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. VII. ANN ARBOR, NOVEMBER, 1890. No. 7.

ORIGINAL ARTICLES.

ESPY'S EXPERIMENTS ON STORM GENERATION.

BY PROFESSOR WM. FERREL.

Under this heading has appeared a communication from Professor Hazen in the September number of the AMERICAN METEOROLOGICAL JOURNAL which, for the sake of readers not well read on this subject, perhaps requires some notice. This paper contains one of a series of attacks on Espy's experiments which have appeared at different times during the last twelve months in the METEOROLOGICAL JOURNAL and in *Science*, the object of which seems to be to overthrow Espy's results, which show that latent heat is set free in the condensation of aqueous vapor, and thus indirectly to overthrow Espy's and more recent theories with regard to storm generation. He says: "Foreign writers, notably Reye, have accepted Espy's work without question. It is entirely safe to say that the sum and substance of all modern theories regarding storm formation take their rise in this work of Espy between 1838 and 1841. The profoundest calculations and speculations upon the development of energy in the free air are based upon a few experiments of the crudest sort made in a small jar."

Now, Dr. Reye refers a few times to Espy's views with regard to the agency of heat given out in the condensation of the aqueous vapor, but in the appendix to his work, where he treats the subject quantitatively, he does not once refer

to Espy, or make use of the results of any of his experiments but refers to Regnault, Zeuner, Clausius and others, since Espy's time. Dr. Reye's researches lead to exactly the same results as those of Sir William Thomson, Clausius, Zeuner, and others, all of which were finally embraced in a convenient formula by Dr. Hann, and published in a paper in the *Zeitschrift* of the Austrian Meteorological Society for 1874. And this valuable paper was subsequently translated by Professor Abbe and republished in the Smithsonian Report for 1877. This formula has been the basis of the physical part of my theory of cyclone and tornado generation. That all modern theories regarding storm formation have taken their rise in Espy's work may be true, but that everything rests upon Espy's experiments is not true. Modern theories are entirely independent of these experiments, and no reference is made to them where quantitative results are inquired into, but the experiments and researches of renowned and more recent physicists only are referred to. Yet, Professor Hazen maintains that nothing has been done since Espy's experiments were made, more than fifty years ago, and that everything still rests upon them. It has never been claimed, even by Espy himself, that his experiments were of a refined and accurate character, and they can be regarded simply as very important first steps. He said that he did not wish it to be understood that the numbers used were strictly correct, and that they were introduced chiefly to illustrate his theory. He claimed that his experiments clearly showed *that the latent caloric of vapor causes the air to occupy much more space when it is imparted to the air than when it is united with water in the form of vapor.* Precisely the same is shown by Dr. Hann's formula referred to above, since it makes the temperature of an ascending current of saturated air greater than that of a current of dry air, in which there is no condensation of vapor in the ascent.

Again Professor Hazen says, with regard to his result in repeating Espy's experiments, that it "gives the death blow to Espy's theory, founded on these experiments, that there can be any liberation of latent heat in the condensation of moisture in the atmosphere." That a professed meteorologist of the present time should assert, and endeavor to prove by means of a "few experiments of the crudest sort in a small jar," that no latent heat is liberated in the condensation of aqueous vapor is astonishing. In both Dr. Reye's expressions, and in Dr. Hann's

formula referred to above, the latent heat of aqueous vapor comes in, which according to Regnault is $r = 607 - 0.708\ t$. In the appendix of my "Popular Treatise on the Winds, etc.," is a table, Number III, which is computed from this formula, and by means of this table I have illustrated on page 232 how, under different assumed conditions, the temperature of ascending air is modified, and increased above that of a current of ascending dry air, from the effect of the latent heat liberated in condensation, and have also shown that this temperature may be considerably greater than that of the surrounding quiet air when the lower strata are a little more warmed up than usual in comparison with the upper strata. According to Professor Hazen, instead of Regnault's value, we should put $r = 0$, for he maintains, as we have seen that there is no heat given out in condensation, and with this value the formula would give 0.99° throughout, instead of the much smaller values in the table referred to, that is, the rate of decrease of temperature with increase of altitude would be the same as in dry air, and hence the energy of the cyclone or tornado would be much diminished. If Professor Hazen can prove by his experiments in a small jar that there is no latent heat given out in condensation, and that we should use $r = 0$, instead of Regnault's value, it must be admitted that the modern theory of storm generation will be at least very much weakened. I am not an experimenter, and must leave this matter with the experimenting physicists of the day.

There is an error in the paper under consideration with regard to the amount of heat arising from the compression of air. It is stated that if the air is compressed 10 inches, that is, from 30 inches to 20 inches, the temperature ought to be raised 163°. The formula for computing this, is:

$$\frac{T}{T'} = \left(\frac{p}{p'}\right)^{0.291}$$

in which T and T' are the absolute temperatures corresponding to p and p' respectively. Putting $p' = 30$ and $T' = 490$ we get for $p = 40$, $T - 49° = 43°$ only instead of 163°. In compressing the air 10 inches, Hazen, by his method, obtained an increase of temperature of only 4°. This, he states, is only about one-fortieth of the theoretical value. It is, however, about one-eleventh part of the true theoretical value. In a compression by the same amount Espy obtained an increase of 36°, as measured

by the amount of rise of the mercury in the gauge after explosion. The true value by the formula above is 45°. Hence, if the formula above is correct this method of obtaining the amount of increase of temperature from compression, is much better than that used by Professor Hazen.

MARTINSBURG, WEST VIRGINIA, September 25, 1890.

ACCESSORY PHENOMENA OF CYCLONES.

BY H. FAYE,
Membre de l'Institut, Président du Bureau des Longitudes, etc.

(CONTINUED).

Whirls at the Cloud Level.—Let us now return to the phenomena which are produced in a certain part of the annular zone comprised between the two bases of a cyclone. This part has received in the United States the name of dangerous octant. It is represented in Fig. 2, of the previous paper at the right of the trajectory of the center (indicated by an arrow). If a parasitic whirl is formed above in the mouth of the cyclone, this whirl is liable to last some time, because the movement of gyration will be found in accord with that of translation. It will turn aside, for its benefit, so to speak, a large part of the cirrus of this region of the cyclone; it will carry it rapidly downward, into the exterior region of calm, where the hot humid air ascends little by little because of the heat of the day, concentrated in a way, under the shelter of the vase-like mouth of the cyclone; it will produce around it an abundant precipitation of vapor and could congeal the droplets. From that time, the parasitic whirl will not only have its fine cirrus to circulate, but also the masses of water or of ice proceeding from the humidity always ascending from the lower air. In consequence of the inertia of these materials continually renewed, and of the increase of centrifugal force, the spirals will enlarge more and more downwards in giving to the whirl the aspect of an hour glass, that is to say, of two frustums of cones placed together by their small bases.* The lower cone spreading more and more, its whirling movement will exhaust itself in

*In tornadoes may be seen similar deformations when the whirls encounter certain obstacles and are encumbered below with debris, with mud and sand, which they carry in their inferior gyrations, and which they expel violently on their circumference (see Finley's Tornadoes of May 29th and 30th, 1879, first Fig. p. 17, second Fig. p. 57, 1 and 2, p. 71, p. 86, etc). This is the hour-glass form.

the thick stratum of rain and ice clouds which it will have formed, or at least it will cease to descend, without losing its movement of translation in that transformation.

This is the special nature of these elevated *trombes*, comprised between the cirrus and the nimbus, to which the name *trombes inter-nubaires* has been given. A long sojourn in mountain regions would be necessary to witness this phenomenon. One of our former geodesists, *M. le Commandant* Rozet, has frequently observed it in the Pyrenees, and thus describes it:

"When the cirrus of the upper regions or rather the cirro-cumulus, forms a stratum more or less continuous, at the same time that a certain quantity of cumulus exists upon the lower stratum of vapor, bad weather may be predicted, or the formation of nimbus. Really the upper clouds soon descend; those below ascend in lengthening into a column vase-shaped above. In the encounter electric discharges are often produced, and nimbus forms immediately. They descend near to the ground launching thunder, rain or wind."

One of our marine officers, Mr. Mellot, whose attention has often been directed to atmospheric phenomena (he is now professor of meteorology in the scientific faculty at Nancy), thus describes these singular *trombes:*

"When a thunderstorm is seen at the horizon, the stormy, dark cumulus or nimbus may be observed, surmounted by a white cloud whose upper part is spread in the form of a mushroom, an anvil or a bell-shaped pavilion which is nothing more than the descending *trombe* of cirrus, to which Rozet has given the name—*trombe inter-nubaire.* Fig. 3 is the design which he himself gives in his course in meteorology.

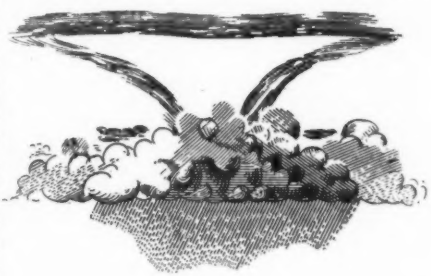

FIGURE 3.

To these secondary whirls where cloud-bursts, hail and even the electricity of thunderstorms are engendered, are attached the inferior whirls, the tornadoes which descend to the ground and whose mouths are placed in the thick, cloudy stratum produced by the first. This we will notice further on.

Hail.—The explanation of this phenomenon results directly from what we have just said about *trombes inter-nubaires.* The first cirrus which descends, whirling in spirals, will not give rise to snow but to little masses of ice needles formed at a very low temperature. This sleet will penetrate farther and farther into the lower clouds, already formed; each grain will congeal around it aqueous particles of cloud already brought to a state approaching freezing. Now, these descending spirals, continually enlarged, are multiple, although centered on the same axis; they possess velocities, temperatures and degrees of humidity which are very different.

The grains of hail, much heavier than air, and passing from one spiral to another in virtue of their centrifugal force, which grows with their mass, will be covered with successive layers of ice,—opaque or transparent. Their fall is very slow, at first, on account of the resistance of the air and their small dimensions; it will doubtless be accelerated as fast as their diameter increases, but even for hail stones of one centimetre diameter, the resistance of the air reduces their fall quickly to a sensibly uniform movement of a dozen metres per second. In addition the generally flattened form of the hail stones, the points with which they bristle and of which the traces are often found after they fall upon the ground, maintain them in the whirl for a certain length of time. Finally, the hail cloud has a considerable thickness which might reach several hundred or a thousand metres; a long time is necessary then for a hail stone to disengage itself entirely, after having passed horizontally in the midst of the cloud for immense distances.

As long as aerial whirls bring down cirrus in abundance, and the cloudy stratum where the whirl spreads and enlarges its base contains water in a vesicular state, the hail will continue to form, to enlarge while whirling, and to fall. And as its horizontal velocity will from that time be quickly destroyed by the resistance of the air, the hail will reach the ground in an almost vertical direction. Besides the aerial whirl progresses with great velocity, and it will constantly encounter new clouds which it will congeal with new cirrus.

This phenomenon will be restricted to the extent of the clouds at the base, or to that of its horizontal distance; the hail will fall upon a long stretch of land, equal in extent to the diameter of the cloud. The duration at a given point will depend on the diameter and velocity of translation.

It will be observed, finally, that these aerial whirls, which form at high altitudes have seldom need to descend far to encounter strata of air sufficiently humid. They pass then, sometimes, like cyclones, above the great features of the surface; chains of mountains 2,000 metres or more in height do not arrest them, while lower elevations arrest tornadoes or prevent them from developing. The theater of these formations is well indicated. It is the region where the progress of superior gyrations is not opposed by that of the cyclone entire, and where the lower space, not reached by the storm, remains free for the vertical development of the phenomenon. This region is in the inclined part of the mouth of the cyclone which overhangs the external, circular ring of the dangerous side, that is to say, to the right of the central trajectory (Northern Hemisphere). It is there, also, where tornadoes are produced, sometimes before, sometimes after the fall of the hail, and often at the same time.

To submit this theory to a direct verification, it would be necessary that a competent observer be plunged for a few minutes into a hail cloud. I can cite such a case, that of M. Lecoq, Professor of Botany in the Scientific Faculty at Clermont:

"August 2, 1835," said M. Arago (*Comptes-rendus*, 1835), in laying before the academy the observations of this scientist, "M. Lecoq was in the very clouds which engendered this meteor. His observations tend to nothing less than to overturn the celebrated explanations of Volta. We accomplish a duty, then, in giving them here as the author noted them upon the spot, without changing a word. If it be remembered, besides, that the academy has recently, at two different times, chosen the theory of hail for the subject of the great mathematical prize, and that accomplished physicists failed to overcome the difficulties of the problem, no one will be surprised at the space given to this extract." August 21, M. Lecoq took his place upon the Puy de Dôme, 1,500 metres in height, to observe a thunder-storm which was advancing in his direction. He was driven from it by an immense lightning flash in which he seemed plunged, and went farther on to a post less exposed, upon the Puy de la Goule. It was 3 o'clock—"the two cloud strata still existed and the south wind, very cold, blew with great force upon the flanks of the mountain. It brought a hail cloud, which seemed well charged, and in which I was then immersed for about five minutes. Hail stones were numerous; the largest were scarcely larger than a hazel nut. They were formed of concentric layers,

more or less transparent, round or slightly oval. They were all animated by a horizontal velocity, but the attraction of the mountain seemed to cause a slight deviation, and some fell upon its sides. A great many struck me without causing the slightest pain and fell as soon as they had touched me. The greater part of the cloud passed above my head, and I heard distinctly the whistling of the hail, or rather a confused sound, formed of an infinity of partial sounds, which I could only attribute to the rubbing of each hail stone against the air. The cloud which passed above my head, and in which all the hail was formed, did not let it fall until a half mile from the place where I stood. A small part, however, spread over the north side of the mountain which intercepted its progress. All these hail stones were animated by a very rapid movement of rotation, but in different directions, as nearly as I could judge in examining their movement at the time of their fall upon my hat, which I held toward them as horizontally as possible. Several other clouds charged with hail came up from the south, and either upon one point or another it hailed without interruption from 1 o'clock until 4, upon the mountain chain, from Mount Dore to beyond Riom and Volvic."

"Between 4 and 9 o'clock the hail ceased, the clouds formed only a single stratum, but they often presented the phenomena which I observed in the morning, that is, they formed in groups, and poured down accompanied by flashes of lightning an immense quantity of water. The south wind being broken, the west wind blew and drove before it these frightful *trombes*."

A similar observation is given in the Pike's Peak observations (p. 465). The observer reports in the following words:

"October 12, 1877. At 11 o'clock A. M. a heavy cloud came over from the west and enveloped the peak; violent thunder followed. At noon the summit was in the midst of a very heavy thunderstorm, which passed to the plains at 1 P. M., affording an excellent observation of the formation of hail. The rotary movement of the hail-cloud could be plainly seen, and with every violent flash of lightning the passing cloud grew perceptibly darker, indicating increasing condensation. The hail formed by this cloud must have fallen about three miles below, for the wood-packers reported quite solid hail at timber line and none above. This verifies the theory that a hail-cloud can be transported laterally several miles while the ice stones are forming."

Hail fell for seven or eight minutes and covered every square metre of ground with about a thousand hail-stones, a centimetre in diameter. The hail cloud furnishing only water at zero (say 290 grammes), it would be necessary that an equal weight of cirrus at 80°, should arrive during seven or eight minutes to change immediately this water into ice and form the thousand hail-stones at zero. But the sources of cold are not the cirrus alone. We must also include the aqueous dust of low temperature which the whirling spirals encounter in their vertical passage, and which contribute to enlarge the first hail-stones.

The air itself, in spite of the compression to which it is subjected in coming from the upper regions, is very cold when it arrives below, after having traversed the cold strata. It is difficult to keep an exact acount of all these circumstances, but it may be said that the hail contains: (1) Cirrus coming from the upper regions; (2) The dust of water at a low temperature gathered up by the cirrus in its vertical passage of several million meters; (3) Water supplied by the hail clouds already condensed and frozen by a previous afflux of cirrus.

On the other hand the three characteristic conditions of the phenomenon, that is, the horizontal whirling of stones observed in the hail clouds, the velocity of translation of ten or twelve leagues per hour, and the short time left for the formation and continual reproduction of the ice which falls over a long band upon the surface, seems to me incompatible with any other hypothesis than that of a descending gyratory movement, progressing with great velocity, like cyclones, *trombes* or tornadoes, determining below it the formation of a special cloud which reproduces itself upon the entire path of the phenomenon, and immediately congeals the product of this condensation.

Electric Storms.—In 1876, when I stated in the "Annuaire du Bureau des Longitudes" for 1877, the preceding ideas, I thought that the prodigious development of electricity in these storms might be attributed to the cirri themselves. If it is true, I said to myself, that atmospheric electricity increases with the height, these cirri ought to be strongly charged; by their rapid descent into the lower clouds, they should give rise to an electric tension which must increase up to the time when a spark or a flash of lightning comes from the cloud to strike the earth or a neighboring cloud. But having given attention to

the lightning flashes and strokes that accompany the eruptions of certain volcanoes, such as Vesuvius, my first opinion concerning the part played by the cirri was modified in the direction of the ideas proposed by Professor T. Luvini, of Turin. According to M. Luvini, these cirri do not carry with them electricity gathered in very high aerial regions, but by their violent friction against the humid air of the lower clouds, they would be a continual source of electricity. And, as the cirri, by their gyratory movements and their density, greater than that of the air, tend without ceasing to recede from the currents of air in which they move, the separation of the two electricities produced by the friction can be maintained. M. Palmieri (Naples) has proven that in the eruptions of Vesuvius, where the vapor of water condensed in clouds is traversed continually by ashes animated by different velocities, these ashes become electrified and give rise to a volcanic thunderstorm.

The most abundant source of electricity which has been discovered up to this time, is certainly Armstrong's machine. It is engendered there by a current of vapor which escapes with strong friction against the inside walls of a wooden spout, and which carries with it torrents of positive electricity if the boiler is placed in communication with the ground.

The condition necessary for the experiment is that the vapor be charged with particles of condensed water;—here are Faraday's own words: "Evaporation is not the only cause of the releasing of electricity when a current of vapor is allowed to escape. I think we must attribute the release to friction, and that it has no relation to the general electricity of the atmosphere; and I also believe, as nearly as I can establish by my experiments, that pure gases, that is to say, without mixture with solid or liquid particles, are incapable of producing electricity by friction against solid or liquid substances."* The vapor of water or air, charged with cloudy particles, produces the same effect upon ice, which takes positive electricity.

Starting with these decisive investigations by Mr. Faraday, M. Luvini considers that the principal factors of storms are:† "(1) A mass of air with a sufficient quantity of vapor of water in the region where the storms originate; (2) *Trombes* with vertical axes descending from above with a quantity of ice-needles at a temperature several degrees below zero. The meeting of these

* *Phil. Trans.*, 1st part, 1848, p. 29.
† *Sept etudes*, Turin, 1884, p. 170, et ff.

two elements or rather the penetration of the second into the first engenders the storm.

"The imposing spectacle of great storms with floods of rain and hail, in the midst of a high whirling wind, out of which come frightful thunder and lightning, is the result of the combined action of the two factors. The whirls, descending with a great quantity of very cold ice-needles electrified, penetrate into the cumulus which they find in their path already formed or in process of formation, and carry an extraordinary quantity of kinetic energy, which is transformed, little by little, into electricity and heat. The needles, feebly electrified in high regions where the mechanical action of more rarified air and the quantity of vapor of water are less, drawn into the spirals of the whirls with a movement which becomes accelerated in its descent, encountering an air denser and richer in the dust of water, become electrified more energetically and re-electrified very promptly, even when for some reason the electricity at first developed has been neutralized.

"It is well to insist upon this circumstance: the generation of electricity in thunder clouds is produced by the relative movement of the solid water, which is found in them, and the air strongly charged with humidity. The more impetuous the wind and the whirl the greater the electrical development, and this condition lasts as long as the new kinetic energy and new ice-needles continue to descend from the upper regions and encounter in their descent a sufficient quantity of vapor of water."

We must observe in the work cited above the development which the author gives to this theory. In his *Contribution à la Meteorologie electrique*, Turin, 1888, he analyses and refutes the more or less opposed theories of Edlund, Palmieri, Exner, Sohnke, etc.

Place of Tornadoes in the Accessories of a Storm.—What is known on this subject seems to me to be well summed up in the following laws formulated by Mr. H. A. Hazen:

"There may be a storm center fairly well marked, though this may be 600 or 700 miles away. Tornadoes almost invariably occur to the south and southeast of this point.

"An extended thunderstorm action is an invariable accompaniment of a tornado."

Everything shows, in fact, that tornadoes are intercalated between cloud-bursts or hail and follow a route parallel to that

of the center of the storm. They evidently have their origin or their mouths in the thick cloud stratum, from which fall torrents of rain or hail, a stratum engendered by the aerial whirls which we do not see.

We must represent to ourselves a complete cyclone, that is to say, a storm with its accessories, like an immense capital, a frustum of a cone reversed, from which hang, *at the right*, long aerial whirls which stop exhausted at a stratum of cloud producing thunder, rain and hail, while the tornadoes hang in their turn from that cloud stratum and descend to the ground. This is what I have tried to represent in Figure 2.

I have followed more completely the singular dependence of tornadoes upon aerial whirls in the annexed figure which lacks the conditions of the generating cyclone.

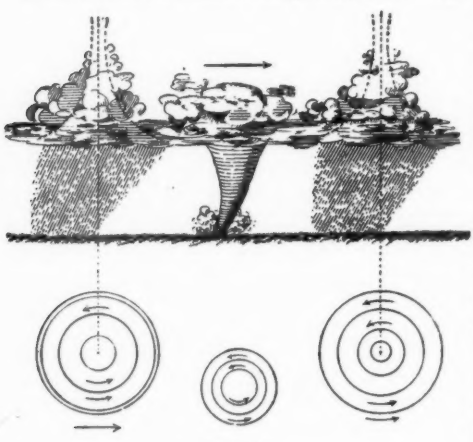

FIGURE 4.

I have called attention in the second article to the fact that the spirals of a tornado which incessantly strike a horizontal soil in the direction of translation but with a much greater velocity, tend to give rise to a momentary current in the same direction. It should be the same at the base of aerial whirls where the velocity of translation and that of gyration join, and where the enormous resistance of the soil does not have to be taken into account. In this current (towards the northeast) the external threads, the least interfered with, should be the most rapid. Gyratory movements will there be formed, and then, from below, their multiple cones may be seen forming and hanging from the clouds. If they succeed in forming into a single one, it would be a tornado followed by torrential rain or hail. Figure 4 represents one of these, in elevation, placed

between the bases of two aerial *trombes*. Upon the ground plan these are indicated by single circumferences with their arrows, and the horizontal current, which proceeds from the cloudy region, is marked by a series of lines parallel to the general trajectory.

From these cloud currents the tornadoes will draw only cold air, fog, or icy droplets. This cold is propagated in descending spirals and will produce around them the cloudy envelope which outlines so well their conic forms. But, inversely, the aerial whirls, their spirals deprived of cirrus, will no longer produce in the inferior air an accumulation of water and ice. The descending spirals keep on their course, contracting until they reach the soil, and exhaust against natural objects all the energy brought from above.

According to this view a tornado should always precede a cloud-burst or hail storm. Mr. Finley's statistics, quoted above, give us 437 cases where the tornado has preceded a rain; but they also give 377 cases where the tornado came after. Before drawing therefrom an objection, the hail which plays the same part as a cloud-burst must be taken into account.

As to the fact that the maximum of frequency of tornadoes follows near the maximum of temperature, this probably depends upon the fact that the aerial whirl has precisely the same maximum. The formation of aerial whirls requires, in fact, great humidity in the upper strata of the atmosphere, varying with the distance of the sun above the horizon, while tornadoes have no need to encounter great humidity in the lower strata which they traverse.

The great frequency of tornadoes in the United States is probably due to the aerial *trombes* favored by the great humidity of the upper strata, which descend lower than elsewhere in these regions. When the hail clouds are very high, between the tropics, for example, tornadoes should form less easily and not succeed even in reaching the ground. It is doubtless for this reason that at the observatory of Zi-Ka-Wei, in China, where typhoons are not lacking any more than humidity is, and where the surface presents few obstacles, I have not found a single tornado in the two years' observations which I have before me at this moment.

Indications of Tornadoes.—The territory menaced at the appearance of a storm is comprised between two lines nearly parallel to the trajectory of the center, tangential to the two

bases of the cyclone, that is to say to the horizontal track of the frustum of the cone and to the horizontal projection of the upper base. The most important thing to know is, if it is possible to obtain in the first of the storm an approximate chart of these two lines, and especially of the central trajectory. This question being of itself of great importance we will investigate it at the close of this article. Let us suppose it answered affirmatively and we will pass to the two limits of the tornado band. Here the isobars give only vague information. The northwest limit may be considered as defined by the force of the wind which varies abruptly near this limit, passing often from an almost absolute calm to the fury of the storm. As to the other limit, equally parallel to the trajectory, and beyond which there can be neither hail, flood nor tornado, resulting from the storm in question, direct observation furnishes no information; the statistics of tornadoes should be consulted to give an idea of the mean distance from that line to the first limit. Storms take a long time to traverse the vast territory of the union: it does not seem impossible then to collect from the first the elements necessary to trace upon a chart these two limits, and there would then be time to notify by telegraph a good share of the population interested in knowing that tornadoes may appear and follow such or such directions through their territory. The population notified will then have only to watch a definite region of the sky for the first signs of the formation of tornadoes.

It would be a real benefit to relieve a whole country from anxiety, where to-day the approach of a storm brings fear of a tornado, although the region may be situated completely outside the menaced zone of that storm.

It is scarcely necessary to repeat that these suggestions are subordinated to the possibility of tracing from the first an approximately correct trajectory of the storm center.

(TO BE CONTINUED.)

THE UPPER YUKON AND THE MACKENZIE.

Mr. William Ogilvie, a Dominion land surveyor, spent the years 1887 and 1888, in an exploration of the Canadian Yukon and the region between it and the Mackenzie. His report on this little-known region is of great interest and is undoubtedly trustworthy. It occupies 114 pages in the Annual Report

for 1889 of the Canadian Department of the Interior. The explorations covered a track survey of nearly 2,700 miles in a wild and almost unexplored country, some portions of which had never been visited by a white man before. Mr. Ogilvie's exploration required energy, enterprise and intrepidity, and his story is told in simple and unpretentious language. From his report the following notes are taken, often in the language of the author:

Mr. Ogilvie began at Chilkat Inlet, the western end of his journey, and worked east. Of the coast range above Chilkat and the vicinity he reports that it is said by those familiar with the locality that the storms which rage in the upper altitudes of the coast range, during the greater part of the time from October to March, are terrific. A man caught in one of them runs the risk of losing his life, unless he can reach shelter in a short time. During the summer there is nearly always a wind blowing from the sea, up Catham strait and Lynn channel, which lie in almost a straight line with each other, and at the head of Lynn channel are Chilkat and Chilkoot inlets. The distance from the coast down these channels to the open sea is about 380 miles. The mountains on each side of the water confine the currents of air and deflect inclined currents in the direction of the axis of the channel, so that there is nearly always a strong wind blowing up the channel. Coming from the sea, this wind is heavily charged with moisture, which is precipitated when the air current strikes the mountains, and the fall of rain and snow is consequently very heavy.

Traveling in the winter is very dangerous, and expulsion of obnoxious men from the mines to the north at this season is considered equivalent to the death penalty.

The Yukon.—During the summer and autumn of 1887, Mr. Ogilvie made his way down the Yukon to the point where it crosses the boundary and here he passed the winter, at a point the longitude of which is 140° 54′ W of Greenwich, and latitude 64° 41′, altitude about 800 above Sitka. The mean barometer corrected for temperature during the stay here was: for October, 28.813, for November, 28.865, for December, 29.058, for January, 29.296, for February, 28.943. The high pressure in January is of interest. Reduced to sea-level, it is 30.3, or 0.3 inch higher than the maximum January isobar given on Hann's map. The mean minimum temperatures were, for October, 18.5°; November, — 5.1°; for December, — 33.6°; for January,

— 25.3°; for February, — 16.8°, and the extreme minima were for the same months in order, — 4.0°, — 24.1°, — 55.1°, — 53.5°, — 52.7°. The mean temperature is not given. The weather was very stormy and snowy. On the way from Chilkat inlet to the boundary station the meteorological record shows a minimum of eight degrees of frost on August 1st, over ten on the 3d, and that four times in this month the minimum was below freezing. On the 13th of September the minimum was 16°, and all the minimum readings for the remainder of the month were below freezing.

These are unsuitable conditions for successful agriculture. The agricultural capabilities otherwise are not great as the land along the river is seldom of good quality. If this country is developed it will be because of its minerals, and it is doubtful if the country itself could provide food for a mining population of any size. The amount of timber suitable for building and manufacturing, along the Yukon, is very small. To give an idea of its scarcity, two of the party made a thorough search of all the timbered land around the head of Lake Bennet and down the lake for over ten miles, and in all this search only one tree was found suitable for making such plank as was required for the construction of a large boat. This tree made four planks fifteen inches wide at the butt, seven at the top and thirty-one feet long. Again, at the boundary line there was required a tree twenty-two inches in diameter at the ground on which to erect a transit. An exhaustive search of over three square miles of the woods there, though showing many trees of convenient size for house logs, and many for small clean planks, showed only one eighteen inches in diameter at a distance of five feet above the ground.

The first snow in the Yukon Valley was seen, on mountain tops September 10th; in the valley September 13th. The temperature of the river water on October 1st, was 38.0°; first drifting ice in river, October 21st; ice set in the river November 15th. The thickness of the ice on December 1st was 14.5 inches; on January 3d, 40.5 inches; on February 3d, 48 inches; on March 2d, 48.5 inches.

The Porcupine and Peel Rivers.—From his station on the Yukon at the boundary, the explorer went northwest in the spring, to Fort McPherson, near the mouth of the Mackenzie. This part of the journey was through an almost unknown country and was made on the Tat-on-duc and Porcupine rivers to a

station on a branch of the latter called La Pierre's house, then by a long portage and the Peel river to the fort. On the Tat-on-duc the water evidently freezes to the bottom in many places, as it is continually bursting up at the sides and overflowing the surface of the ice, where it is soon frozen. Hence in the spring the ice in places must be of enormous thickness. About eleven miles up, a creek flows in from the north. According to the Indians, it comes out of the side of the mountain some distance up; they described the water as being warm where it emerges, this being, perhaps, the place to which they had referred as mentioned above. Whether this is true or not, the water where it enters the river is not frozen, nor is it frozen for some distance below this point. This is the point from which the river takes its name of Tat-on-duc, or in English, Broken Stone River, for here it appears the river is always open, and there are many large masses of rock in the channel. Except on the theory of warm water coming into the river, Mr. Ogilvie cannot account for its being open here at the time he saw it, when almost everywhere else it was frozen, even in places where the current is much swifter and rougher than here, where it is quite tranquil.

About twenty-five miles up the river a small canon was reached; the water way is rough, but the sides, though perpendicular, are not high. About four miles above this the Indians reported a small lake in a deep valley, which never freezes. They appeared to have a superstitious dread of it, saying something about a strong wind always blowing into it, which makes approach dangerous. Around it, they said, many sheep and goats are to be seen, which can be accounted for by the fact that no one ever hunts there. They pointed out the position of the lake as well as they could from the river. It lies in a deep valley at the foot of a very high mountain, which they call Sheep Mountain, the height of which above the river was estimated as at least three thousand five hundred to four thousand feet. From the barometer readings along here, the river is not less than one thousand four hundred feet above the sea, so that this peak is upwards of five thousand feet above sea level. About three miles above this peak another small but very rough canon is passed on the river. Three and a half miles above this there is, on the east bank of the river, a low swampy place, from which there is an effusion of sulphureted hydrogen gas. The odor is quite strong for some distance along the river. An Indian

reported that there was much of the same gas escaping at the lake already referred to. The danger of the lake is apparently due to violent rushes of the gas, which makes men sick, so that they fall down and roll into the lake.

A short distance further there enters from the east side a creek which had to be ascended to avoid an impassable canon on the main river. According to the Indians this canon contains a high waterfall, which it is impossible to pass, and they describe it as the largest and worst canon on the river. They had to ascend this creek about four and a half miles, when they turned off to the left, going up a narrow valley which lies between two high bald mountains, on the bare sides of which they saw many wild sheep feeding. The mountain on the west side of the pass was named Mt. Deville; that on the east side, Mt. King. The bed of the creek by which they left the river is wide and shallow, and the water runs on the top of the ice, thus continually adding to its thickness, till in many places it has the appearance of a small glacier. Mr. Ogilvie was quite sure that there are places on this creek where the ice remains all summer.

From the station on the Yukon at the boundary to one on the Porcupine (Long. 139° 43′, Lat. 65° 43′) the following notes on the climate are given:

The lowest temperature in the month of April was on the 4th 37° below zero, and for six days afterwards all the minimum temperatures were below 30° below zero. The last time the thermometer registered a minus reading was May 5th, — 1.8°. The highest temperature in April was on the 30th, 40° above zero. The highest temperature in May was on the 7th, 55°. The first time the snow showed signs of melting was April 29th. The first appearance of insect life was April 30th, when a small fly came out of the river in great numbers, flying about and crawling over the snow. The water in the river began to rise on May 6th. The first geese were heard flying overhead on May 8th; they were flying in a southwesterly direction, as though they had come from the Mackenzie. The common house fly made its appearance the same day. The first swans were heard May 11th. First mosquitoes seen May 14th. First cranes heard May 15th.

Notwithstanding the high altitude and latitude, the timber and shrubbery in the bottom of the valley grew as large and strong as on the upper Lewis, in five degrees lower latitude. Surrounding the camp was a timber-covered flat about two

square miles in area, on which grew many nice trees upwards of a foot in diameter. Nearly all of these were spruce, but there were also some clumps of cottonwood, the trees in which averaged nearly as large as is the same species along the Athabasca and Peace Rivers. Willows are abundant along the streams, and grow as large as they generally do in other parts of the territory, being not unusually four or five inches thick. A few white birch were seen. No timber was noticed out of the immediate bottom of the river valley.

Jams of ice in the rivers were very common through the spring and early summer.

The Mackenzie River.—Mr. Ogilvie collected a series of notes on the opening and closing of the Mackenzie which we give in his own words.

"Some notes as to the time during which this great stretch is open to navigation will serve both commercial and meteorological purposes. At all the Hudson's Bay Company's posts a journal is kept of all proceedings at the post, and of every event of note in the vicinity. From these journals can be ascertained the dates of the opening and closing of the river at the respective posts ever since they were built. From the officers at Forts Norman, Simpson and McMurray, I obtained data which I here submit. The date on which the ice broke up is given in each case, but as a rule, the river was not clear of running ice until nearly a week later.

FORT NORMAN—LATITUDE ABOUT 65°.

Year.	Ice Broke Up.	First Snow.	First Ice Formed.	River Closed.
1872	Not given.	September 28th.	October 7th.	November 8th.
1873	May 17th.	September 28th.	October 21st.	November 12th.
1874	May 25th.	October 15th.	November 2d.	November 18th.
1875	May 24th.	Not given.	October 23d.	November 9th.
1876	May 19th.	October 10th.	October 13th.	November 9th.
1877	May 12th.	September 25th.	October 18th.	Not given.
1878	Not given.	September 28th.	October 22d.	November 7th.
1879	May 9th.	October 3d.	October 20th.	November 2d.
1880	May 22d.	October 7th.	October 22d.	November 12th.
1881	Not given.	October 2d.	October 7th.	November 12th.
1882	May 14th.	October 9th.	October 14th.	November 14th.
1883	May 11th. *	October 9th.	October 24th.	November 10th.
1884	May 28th.	Rest of record lost.	——	——
1885	No record.	No record.	No record.	No record.
1886	No record.	No record.	October 18th.	November 13th.
1887	May 24th.	September 23d.	October 5th.	November 8th.
1888	May 19th.			

In the record given below—for that part of the Mackenzie below the mouth of the Liard, it must be borne in mind that the Liard being a mountain stream and rising in a somewhat warmer climate, opens before the Mackenzie River, which has also the disadvantage of having a large body of still water near at hand in Great Slave Lake.

*River was not clear of ice this year until May 28th.

FORT SIMPSON—LATITUDE 61° 52′ N.

Year.	Ice Broke Up.	First Drift Ice.	River Closed.
1876	May 14th.	November 4th.	November 17th.
1877	May 8th.	November 1st.	November 28th.
1878	May 8th.	October 16th.	November 26th.
1879	May 3d.	November 12th.	November 20th.
1880	May 7th.	November 2d.	November 26th.
1881	May 13th.	October 12th.	November 18th.
1882	May 7th.	November 1st.	November 30th.
1883	May 1st.	October 28th.*	November 20th.
1884	May 12th.	October 11th.	November 18th.
1885	May 2d.	October 28th.	November 20th.
1886	May 13th.	October 30th.	November 25th.

The dates of the breaking up of the ice in the Mackenzie above the Liard for the same years are as follows:

1876.....Not given.	1882.....May 20th.
1877.....May 19th.	1883.....May 5th.
1878.....May 17th.	1884.....May 14th.
1879.....May 19th.	1885.....May 7th.
1880.....May 19th.	1886.....May 27th.
1881.....May 19th.	

The river is always open some time before the lake. In the latter the ice floats around for some weeks before it is sufficiently broken up to pass down the river. In 1888 it was well on in July before the lake was clear enough to enable the steamer to proceed to Fort Smith, but that was an unusually late season. As a rule, I believe, navigation on the lake opens in the last days of June. At Fort McPherson on Peel River, the ice does not generally leave until the 1st of June. On Lake Athabasca the ice goes a little earlier than on Great Slave Lake; but this does not affect the question of the navigability of the Mackenzie, which cannot be reached until Great Slave Lake is clear.

At Fort McMurray, situated at the foot of a long series of rapids on the Athabasca River, I obtained the following notes of the breaking up, drifting and setting of the ice. This point is in about latitude 56° 40′.

Year.	Ice Broke Up.	First Drifting Ice.	Ice Set. River Closed.
1878	April 18th.	October 27th.	No record.
1879	No record.	October 26th.	November 1st.
1880	May 2d.	November 14th.	No record.
1881	April 21st.	October 14th.†	November 12th.
1882	April 24th.	November 1st.	November 8th.
1883	April 25th.	October 30th.	November 10th.
1884	April 27th.	October 18th.	October 28th.†
1885	April 9th.	October 23d.†	November 13th.
1886	April 16th.	November 4th.	November 14th.
1887	April 27th.	October 22d.	October 24th.
1888	May 4th.	November 3d.	November 9th.

As to forest growths on the lower Mackenzie, the timber, large enough for commercial or manufacturing purposes, is all in the river

*The first drift ice in the Mackenzie this year was seen November 1st.

†In these years the river became clear of ice for some time, after which drift ice again appeared, until finally the ice set and closed the river.

valley. On the plains above the trees are small and unfit for anything except for fuel or the few uses to which trees six or eight inches in diameter can be applied. There is some fine material for lumber on some of the islands in the river, but many are bare with the exception of a few willows. It may, in short, be said that, away from the immediate vicinity of the river, there is no timber of value in the sense in which the term is used in the east, until we get above Fort Wrigley, and then in some places the banks are low, flat, and swampy, with trees much larger than those on the higher lands, many of them being fit to make fairly good lumber. On the flats between Fort Simpson and Great Slave Lake as well as on those adjoining the lake, there is also much forest that would yield a large amount of good sized spruce and poplar.

The level country surrounding the lower half of Great Slave River is all well timbered with fine large spruce, equaling in this the lower Athabasca and Peace Rivers, and I think, when the time comes, that here will be found this district's principal supply of lumber. On the high, light soil around Fort Smith, the trees are small and generally of no value except for fuel. Along the river, between the rapids and Lake Athabasca, there are many small areas of flat, swampy ground which would supply some very fair timber.

It may be said generally of the lower Mackenzie that the timber along it is only sufficient to supply the needs of the immediate vicinity. On the upper river the surplus is not sufficient, and the market not convenient enough to justify manufacturing, until existing conditions are greatly altered.

The varieties of trees along the lower part of the river are few, spruce, with a few small tamarac, some small birch, and a few poplar, constituting the bulk of the forest. The spruce far outnumber all the rest. On some of the islands there is much shrubbery, willows and alders growing in profusion in the swampy places; but in general the undergrowth is stunted and thin, especially on the uplands.

Everywhere, the explorer thinks, the Mackenzie basin is quite as capable, so far as quality of soil is concerned, of supporting an agricultural population, as the greater part of the Provinces of Ontario and Quebec. The soil as seen from the river is generally good; and the probability is that it continues so at least as far back from the stream as the woods extend. This extent is said to vary from twenty to forty miles on the east side, where no stream flows in, but, where there are streams, the distance is much greater as the timber follows the valleys. Beyond the fringe of timber we come to the so-called barren lands, on which nothing but mosses and lichens grow, and which, except as the pasturage of the musk ox and a few other animals, are practically useless, so far as known at present. On the west side of the river the woods extend to the timber line on the mountains.

As Mr. Ogilvie's conclusions as to the climate and capabilities of this region will be new to most readers in the States, we give them in detail with the facts on which they depend.

Assuming the limits to be as above, the area of the fertile soil can readily be found. Speaking only of that portion of the Mackenzie basin extending from Athabasca Lake to the Arctic Ocean, we have a strip of

land nine hundred and forty miles long and something over sixty wide. This gives in round numbers sixty thousand square miles of land, the agricultural capabilities of which we may reasonably discuss. I think the above area is less than that actually wooded, but on the west side much of the surface is probably at such an elevation, being near the mountains, as to be outside the limits of our discussion. Theoretically the points involved are the prevalent temperatures during the growing months, the period of vegetation, and the duration of sunshine.

I do not know of any regular record of temperature having been kept at Fort McPherson, the most northerly point at which any one is permanently settled in the district. The only information on this point which I have is my own record for the last ten days of June while I was camped in the valley near the fort. The lowest temperature during that period was 37.3° F. on the 20th, and the mean minimum from the 20th to the 30th was 43.3° F. The highest observed temperature during the same period was 74° F. at 1:30 P. M. on June 21st, and the mean temperature at that hour for the ten days was 62° F. The lowest of these temperatures would not injure vegetation. The mean minimum for the whole month would be below this, probably two or three degrees, but even that would not arrest vegetable growth. When, in connection with the temperature, we consider the number of hours of sunshine during June and July, it seems evident that Fort McPherson has all the essentials for the successful cultivation of most cereals and vegetables. At this northern point refraction extends the time during which the sun does not set, so that there are twenty-four hours sunshine each day from about June 1st to July 15th. On May 1st the sun is up for seventeen and one-half hours, and during August the hours of sunlight vary from nineteen on the 1st to fifteen on the 31st. The total hours of sun are seven hundred and six in May; seven hundred and twenty in June; six hundred and eighty-four in July; and five hundred and twenty-seven in August; in all two thousand six hundred and thirty-seven hours of sun out of the total, day and night, of two thousand nine hundred and fifty-two in the four months. As twilight continues while the sun is less than eighteen degrees below the horizon there is actually no darkness during this period. When the temperature is suitable, vegetation under these conditions thrives to an almost incredible degree, as the following shows. When I arrived at Fort McPherson on June 20th the new buds on the trees were just perceptible, and on the evening of the 22nd the trees were almost fully in leaf.

The mean minimum temperature for the month of July was 45.4° F. The mean temperature for 1:30 P. M. was 64.7° F., but on two occasions the thermometer went to 78° in the shade, and ten times to 70°. These temperatures were noted along the river, at different points of course, although during the greater part of the month my latitude did not change very much.

This combination of favorable temperature and long hours of sunlight promises well for vegetable growth, but there are interfering causes. Unfortunately, snow storms are apt to occur at any time in the year at Fort McPherson. On July 2nd, five inches of snow fell and the thermometer went down to 25° (7° below freezing point), yet, strange to say, the frost did not appear to hurt anything. A northeast wind, con-

tinuing for a day or more, lowers the temperature in a few hours from pleasant summer heat to what reminds one of the approach of winter.

As far as I could learn, no attempt at cultivating cereals or roots has been made at Fort McPherson. But at Fort Good Hope some of the people grow potatoes and other garden produce; and, as the difference of latitude is not much over a degree, the same things ought to grow nearly as well at Fort McPherson. The potatoes grown at Fort Good Hope are small, averaging about the size of large hens' eggs. Those which I tasted were bad, as if they had been frozen; but they were of the previous season's growth, and it was then the middle of July. Even in Ontario potatoes of that age are not very palatable. This tuber appears to have always vitality enough to increase, as at Fort Good Hope they have had no change of seed for several years. This tends to show that the frosts are not very severe during the time the potatoes are growing and ripening. When I passed, the onions, lettuce, and other things planted in the gardens were pretty well advanced, the onion stalks being about as large as pencils. No cereals had been sown, but I think barley would succeed fairly well. I am not aware of any continuous record of temperature at Fort Good Hope; so I cannot say whether the climate at that place is suitable for the growth of plants during June, July, and August. While I was there the days were pleasant and warm and the nights not unpleasantly cool. Nor, if we omit the 2nd of July, when snow fell, did I note anywhere any temperature below freezing during July and August.

It may be said that my observations extended over too great a range of latitude to be of any value in indicating the temperature at any period or any place, as, while they were being taken, we were constantly moving south. This is true. But it must be remembered that in moving south we were leaving the area of constant sunlight and getting to where night has a cooling effect, so that the objection has not the same weight it would otherwise have.

The statement given below of the duration of sunlight in the months of May, June, July, and August, serves to show that a difference in latitude has not the same effect in changing the summer temperatures of places in high latitudes as it has in more southerly localities. Unfortunately, the records at posts in the district are too few and meagre to either confirm or disprove this theory, and to use the records of such places as Fort Franklin, on Great Bear Lake, and Fort Rae, on Great Slave Lake, is hardly fair. These points are over three hundred miles apart in an air line, and the temperature at either or both may be influenced by the local conformation of the ground, or other unknown causes. However, taking the records at these places, we have the following comparison:

Mean Temperature during	Fort Franklin, lat. 65° 12′	Fort Rae, lat. 62° 40′
May	35.2° F.	27.7° F.
June	51.4°	51.4°
July	52.0°	61.2°
August	50.6°	56.5°

The Fort Franklin data are given in Professor Loomis' Meteorology, published in 1875. He gives as his authority Dove's tables in the report

of the British Association for 1847. Who the observer was is not stated, but it was probably Franklin. The Fort Rae statistics were furnished by Mr. Carpmael to the Senate Committee appointed to inquire into the resources of the Mackenzie basin, and cover the same months as those given for Fort Franklin. These statistics, as far as they go, confirm the theory, for the extremes at Fort Franklin differ 16.8°, while at Fort Rae the difference is 33.5°, and the monthly differences at the former place are much less than at the latter.

I have computed the following table which shows comprehensively the different durations of sunlight for the latitudes of Ottawa and Forts Chipewyan, Simpson, Good Hope, and McPherson:

	Ottawa.	Chipewyan.	Simpson.	Good Hope.	McPherson.
Latitude	45° 26′	58° 43′	61° 52′	66° 16′	67° 26′
	H. M.	H. M.	H. M.	H. M.	H. M.
Hours sunlight, May 1	14 08	15 34	16 05	17 06	17 30
" " June 1	15 16	17 36	18 39	21 04	24
" " June 21	15 30	18 44	19 14	22 48	24
" " July 1	15 24	18 36	19 02	22 04	24 00
" " August 1	14 32	16 16	16 56	18 16	19 24
" " August 31	13 08	13 52	14 08	14 36	14 44
	Hours.	Hours.	Hours.	Hours.	Hours.
Hours sunlight in May	456	514	538	592	706
" " June	462	549	570	662	720
" " July	464	530	558	625	684
" " August	423	467	481	519	527
Totals	1,805	2,060	2,147	2,398	2,637

The number of hours of sunlight in each month has been obtained from the mean of the numbers at the beginning and ending of the month. This does not give a strictly correct result, as the sun's declination, on which the length of the day depends, does not change uniformly, the daily change in June, when the sun has attained its greatest declination, being small as compared with that in September when the sun is near the equator. Were the light of each day in the period separately computed, the totals would show even more difference in favor of the north. In computing the above table, refraction has not been taken into account, except in the case of Fort McPherson. Allowance for refraction would increase the duration of sunlight at all the other places; but much more in the north than in the south. As the table now stands it assigns to Fort McPherson eight hundred and thirty-two hours, or thirty-four and two-thirds days, more sunlight than Ottawa during a total period of two thousand five hundred and fifty-two hours. A better mode of comparison is to reduce the number of hours of sunlight at each place to days. It stands thus: Ottawa, seventy-five days, five hours; Fort Chipewyan, eighty-five days, twenty hours; Fort Simpson, eighty-nine days, eleven hours; Fort Good Hope, ninety-nine days, twenty-two hours; Fort McPherson, one hundred and nine days, twenty-one hours, and this out of a total of one hundred and twenty-three days.

At Fort Norman the Hudson's Bay Company had a garden planted

with turnips, potatoes, and other garden produce. I was at that point during the last days of July, at which time potato vines were from six to ten inches long, and did not promise a good yield. The Roman Catholic Mission had two patches, together about an acre in extent, planted with potatoes. The soil here was much better than in the first patch, being a warm clay loam, while in the other it was nearly all decaying vegetable matter, commonly called "muck." The mission potatoes were much stronger in the vines than the Hudson's Bay Company's, and, at that time, nearly covered the ground. The Anglican missionary had planted a small piece of ground near the river on a sheltered bench below the top of the bank and facing the south. Here the growth was much stronger than at either of the other places. Some barley had been sown in it and was well grown, the stalks averaging from two to two and a half feet high, and the heads being long and just beginning to fill. The growth of grass on this flat is luxuriant, and nettles grow as strong and large as any I have seen elsewhere. Near the edge of the woods wild vetches grow as long and vigorous as they do near Edmonton. Everyone complained of the cold, wet weather which prevailed during the summer and much retarded vegetation. The Roman Catholic missionary, in charge of the mission here, told me that in twenty years' residence at the place he did not recollect such a cold, damp, cloudy summer.

At Fort Wrigley some slight attempts had been made at cultivation, but I do not consider them a fair test of the capabilities of the place. When I was there, on August 15th, the people were gathering blueberries, then fully ripe and as large and well flavored as they are in Ontario. Ripe strawberries were found on August 9th, ninety miles below this, and a few raspberries soon afterwards. Above Fort Wrigley wild gooseberries and both red and black currants were found in abundance, some of the small islands being literally covered with the bushes. The gooseberries were large and well flavored, and the currants would compare favorably with the same fruit as cultivated in the vicinity of Ottawa, the black currants being especially large and mellow. This was in the middle of August, in latitude 63°.

At Fort Simpson the Hudson's Bay Company has a large plot of ground planted with potatoes, turnips, onions, and other garden produce, such as is generally grown without artificial means in Ontario. On August 24th when I visited this place the growing vegetables looked almost as good as the same kinds seen on the Ottawa market at the same date. Lettuce particularly was very large and fine. There was also a large area of barley which looked well and promised an abundant return if allowed to ripen. The grain was then full and plump and just beginning to harden; but fears were entertained that a frost might come and spoil it. The people there claimed that the prevailing cool, cloudy weather had retarded its growth, as otherwise it would then be out of danger from frost. This cereal has been grown with success at Fort Simpson for many years. I understood that wheat had been tried, but with indifferent success. The garden altogether presented an appearance hardly to be expected at a point eleven hundred and fifty miles farther north than Ottawa. It is situated on an island in the river, and the presence of the large body of water may moderate the climate and

account for the fine appearance of the garden. Whether the same favorable result can be attained a mile or more away from the river can only be decided by trial. I am strongly of the opinion that it cannot.

On the high river bank below Fort Providence wild gooseberries and currants were very plentiful, though on the 8th of September they were somewhat over ripe.

At Fort Providence the usual garden produce is grown every year and generally turns out well. Barley is also grown with success; but in 1888 it was, as everywhere else in the valley, much retarded by cool weather. Up to my departure from the post, the lowest temperature exclusive of 2nd of July, was 31.8° on August 29th. The mean minimum for the month of August was 43°. When I was at Fort Providence the barley was beginning to change color, and, unless a very severe frost came soon after, would ripen. Wheat has been grown here for many years by the Hudson Bay Company, generally being fairly ripe before it is touched by frost, and sometimes escaping altogether. The wheat is ground in a small hand mill, and the flour used in the ordinary way by the people of the fort. While there I ground a few pounds of the crop of 1887 and had the flour made into a cake, which, though not quite so good as that made from XXXX flour, was palatable, and would probably sustain life as effectually as any other, those using it appearing as well and strong as could be desired. I brought home a sample of this wheat for inspection.

At Fort Resolution the Hudson's Bay Company were growing potatoes, turnips and barley. The first two were of good quality and size; but there would be no yield of the last. The Anglican missionary also had a garden in which were potatoes, cabbage, cauliflowers, turnips, onions, and peas, the latter still green on 21st September. The potatoes and cauliflowers were both good in size and flavor. I was informed that small potatoes were grown in a garden at Fort Rae, situated on a long arm of Great Slave Lake; but, according to report, there is not much land around the lake available for farming, even were the climate suitable, as it is nearly all rock. At Fort Smith nothing of importance from an agricultural point of view had been done and the autumn frosts were very severe.

Samples of seeds from the Central Experimental Farm were received at all the posts, but too late for planting in 1888. If proper attention is given to them, as I believe it will be at most points, the results will be very interesting and instructive as a practical test of the capabilities of the country.

In conclusion, I may say that I do not wish to be understood as representing this country as suitable for agricultural operations, as I do not think it is. I have merely presented the results of the attempts which have been made. These results are doubtless much more favorable than might be expected; but how far they would hold good elsewhere than in the immediate vicinity of the river is not known. It is probable that the presence of such a large volume of water, with a temperature of about 55°, has a beneficial influence on vegetation.

Before that part of our territory will be required for settlement, there will be ample time to determine by experiment exactly what it is worth for agriculture. In looking over the world for countries lying in the

same latitude to compare with it, we find Norway extending from latitude 58° to 70° 30', with an area of one hundred and twenty-three thousand two hundred and six square miles, and a population of one million eight hundred and six thousand nine hundred. Of her territory only about one-thirtieth is under cultivation, one-fourth being covered with forest, and the rest barren mountain land. But as Norway is exposed throughout its whole length to the Atlantic Ocean, the comparison is hardly apposite. Better suited for comparison is that division of Russia known as Finland, lying between 60° and 70° north latitude, with an area of one hundred and forty-four thousand two hundred and fifty-four square miles, and a population of two million one hundred and forty-two thousand and ninety-three. This shows us that we must not regard the district as altogether useless nor despair of its ultimate occupation to at least the same extent as the countries named.

Aurora.—Of this phenomenon, the author says:

No regular record of the appearance and brilliancy of the aurora was kept during my stay at the Boundary. Nothing unusual was noticed in this connection, except its appearance two or three times in daylight. The first time I saw this phenomenon my attention was drawn to a long, thin, streamer-like cloud; as the air was perfectly calm it excited my curiosity and I watched it closely, noticing all the fluctuations in intensity, sudden increase and decrease in extent, and quickly shifting movement of the aurora. It was noticed again on two or three occasions and observed closely, to determine whether or not it was aurora, but always with the same result. It could have been nothing else. It was of about the brilliancy of pale aurora when seen at night, although the sun at the time was well above the horizon. Several members of the party observed all these appearances as well as myself. This phenomenon has been seen by several others. (See Encyclopædia Britannica, Vol. III, pages 90-91).

As to the aurora making an audible sound, although I often listened when there was a very brilliant display, and despite the profound stillness which is favorable to hearing the sound, if any sound occurs, I cannot say that I ever even fancied I heard anything. I have often met people who said they could hear a slight rustling sound whenever the aurora made a sudden rush. One man, a member of my party in 1882, was so positive of this that, on the 18th of November, when there was an unusually brilliant and extensive display, I took him beyond all noise of the camp, blindfolded him, and told him to let me know when he heard anything, while I watched the play of the streamers. At nearly every brilliant rush of the auroral light he exclaimed: "Don't you hear it." All the time I was unconscious of any sensation of sound.

Green Clouds.—A phenomenon, apparently rare, was observed twice in the month of February, first on the 19th, and again on the 29th. This was green clouds. The display on the 19th was extensive and very beautiful; that on the 29th not so much so. The phenomenon was seen in the morning, just before sunrise, and on both occasions the sun was covered with downy, white clouds, while there was a very slight fall of minute ice crystals,

accompanied by a much higher temperature than usual. The color was a brilliant emerald green, fringed on the lower side with yellow, which, as the sun gradually rose, encroached on the green, until the clouds were all yellow. This color changed to orange and red after the sun had risen above the horizon. The first time the green color lasted about a quarter of an hour; the second, only a few minutes. It is probable that the form of the snow crystals in the air produced abnormal dispersion and made the green rays of the spectrum conspicuous.

METEOROLOGY, ETC., AT THE BRITISH ASSOCIATION.

There were few strictly meteorological communications presented to the Mathematical and Physical Section at the Leeds meeting, which was presided over by Dr. J. W. L. Glaisher, F. R. S. The following reports of committees were read, the first being that on the

Ben Nevis Observatory.—It stated that during the past year observations had been made continuously at the top of Ben Nevis and at the sea-level at Fort William. Mr. Omond had completed an important investigation of the temperature of Ben Nevis and the wind forces, and Mr. Rankin had photographed clouds and other meteorological phenomena. In the autumn of last year a grant of £50 was obtained from the Government for carrying on an investigation into the numbers of dust particles in the atmosphere. Messrs. Omond and Rankin were still engaged with the inquiry into the direction of the winds observed at the top, with the winds observed at low level stations at the same hours, and their relation to the weather of North-Western Europe. The comparative frequency with which the winds at the observatory blow not with but against the isobars of low level stations indicated a force widely different from the barometric gradients of the weather maps of the Meteorological Office and were striking elements in the meteorology of Ben Nevis. At Fort William the mean temperature was 0.8 under the average, the greatest defect from the mean being 1.8 in February, and the greatest excess 5.6 in May. The noteworthy feature of the meteorology of the year was the all but unprecedentedly high temperature of May, a temperature, as regarded Scotland, only once exceeded since 1764. At the top of the Ben the excess above the mean was greater, amounting to 7.7°, as happened during all unusually high summer temperatures. The minimum

temperature on Ben Nevis was 6.4°, which occurred at 7 A. M. of February 10th. This was absolutely the lowest temperature which had been recorded since the opening of the observatory in December, 1883. The maximum was 61.8° on July 4th. Thus the extreme range of temperature for the past year was 55.4°. The registrations of the sunshine recorded showed 634 hours of sunshine, as against 970 hours of the previous year, the latter year thus showing a half more hours. The largest number, 213, was recorded in June; the lowest, 9, in August, being the lowest that had occurred hitherto in any summer month. As the highest possible hours for the whole was 4,470, sunshine prevailed on the top of the Ben during only one hour in seven in 1889. The amount of the rainfall during the past year was 120.66 in., being about 10 in. less than the average, the least rainfall being 1.94 in. in June, and the greatest 18.04 in. in December, and 17.69 in. in January. The importance of the investigations conducted at Ben Nevis in their relation to cyclones and anticyclones was touched upon, and in future meteorological data will be made with a view to better forecast the weather. They recommended that the committee of the section be reappointed, Lord McLaren being chairman in place of Mr. Abercromby, whose health compelled him to live abroad, and a grant of £150 will be proposed.

Tidal Observations in Canada.—The sixth report of the committee for promoting tidal observations in Canada, stated that the Canadian government has at length undertaken to establish stations for systematic tidal observations, and that the calculations for the tide tables will be made according to the method recommended by the Association. It is understood that the construction of the tables will be entrusted to Mr. Roberts, of the Nautical Almanac Office. That the efforts of the committee were not successful earlier is possibly due to the fact that there have been three Ministers of Marine in succession since the committee was appointed and that the committee had, in each case, to begin *de novo* to present the facts to the Minister in office, in order to convince him personally of the need of the observations for the purpose of practical navigation. The character of the British Association as scientists, was to a certain extent, a positive obstacle to the efforts of the committee, instead of an aid. Notwithstanding the courtesy with which deputations from your committee were invariably received by the Minister or the Cabinet on the occasions of an interview, it

was obvious that there was always lurking in the background a suspicion that the committee might, not unnaturally, take an exaggerated view of the practical value of the observations, in their appreciation of the scientific interest of their results, and this, notwithstanding the fact that there is not at the present moment a single official tide-table, giving the rise and fall of tide, for any of the ports of the Dominion, and that ocean steamers run aground in places where they ought not if sufficient information were supplied them. Nor is information as to the tidal currents obtainable, though the want of it is the cause of numerous wrecks and great consequent loss of life and property, as shown by the annual wreck list for years past.

Earthquakes in Japan.—The tenth report of the committee appointed for the purpose of investigating the earthquake and volcanic phenomena of Japan, drawn up by the secretary, Professor John Milne, was then read. This gives a great number of statistics with regard to volcanic disturbances in Japan. Among other things it states that, as in previous years, in Central Japan, where there are many earthquakes and many volcanoes, the earthquakes, or at least the majority of them, did not come from volcanoes. In the Kü peninsula where there are no volcanoes, there have been many earthquakes; but there are also districts, as, for example, the southern extremity of Kiushiu, where there have been a fair number of earthquakes, where it is possible such disturbances may be directly connected with the proximity of volcanoes. On the whole, however, there is no reason to consider that the majority of earthquakes are in any way connected with volcanoes. There were many accounts of magnets and magnetometers having been affected at or about the time of earthquakes. The magnetic disturbance following the eruption of Krakatoa in 1883, progressed westwards and northwards at rates of from 761 to 939 miles per hour, which is apparently a rate very quick even for a dust cloud to travel. At or about the time of earthquakes, electrical phenomena appear to be more frequent and more pronounced than magnetic phenomena, and the records of such phenomena are found in the description of many large earthquakes. Records which are of value in determining the velocity of earthquake transmission have not yet been obtained, but one or two of the observations, which have extended over a period of two years, suggest that at least sometimes a given earthquake may be felt simultaneously over an area of considerable extent. This was the case

with the disturbance of August 2d, 1889, which was noted at several places about 100 miles apart at exactly the same time. At present there are reliable observations on the propagation of earth-waves varying between 200 and 6,000 meters per second, whilst at other times it appears as if a large area received an impulse in all its parts at the same moment.

Reports of the committees for comparing and reducing magnetic observations and for determining the seasonal variations in the temperature of lakes, rivers, and estuaries were also read.

Mr. A. L. Rotch, who was a member of the Sectional Committee, read a paper on a meteorological observatory recently established on Mont Blanc, which will be published in full in this JOURNAL.

Mr. J. Hopkinson presented three papers on the climatology of certain sections of Great Britain. The one which had the most general interest was on

The Inland Compared with the Maritime Climate of England and Wales.—Mr. Hopkinson in this paper endeavored to show that the chief difficulties in making a satisfactory comparison between the inland and the maritime climate would be removed if a sufficient number of meteorological stations could be found which represented approximately the mean height and the range of the height of the land in the interior and near the coast, and if the mean position of both the inland and the maritime places were almost identical and not far distant from the center of England. To fulfill these conditions the author selected five stations to represent the interior of the country, and five to represent the sea-coast. He said that his researches led him to the conclusion that in every respect so far as comfort was concerned, and most probably health also, a maritime climate was superior to that found inland. It was warmer and more equable in temperature, the nights not being nearly so cold and the days no hotter. The air on the sea-coast was less humid and the sky less cloudy, and less rain fell. As regarded the latter, if Buxton, one of the inland stations, was left out of consideration, the rainfall would be found about equal on the coast and inland; but Buxton might be taken as fairly typical of places situated at a fair elevation above the sea.

On Meteorological Photography.—Mr. Hopkinson called attention to the increasing importance attached to photography as a means of illustrating scientific subjects and aiding in scientific research. In no branch of science could photography be of

greater value than in the elucidation of meteorological phenomena, owing to the transient nature of such phenomena. He advocated the appointment of a committee of the British Association on meteorological phenomena, by whom instructions to photographers would be issued with a view of instituting a systematic method of working.

Some photographs of clouds by Mr. Friese Greene were exhibited, and Mr. Glaisher mentioned that on one of them there were four clouds shown which were not visible to the naked eye, and that was brought about by taking the negative through yellow glass. Mr. Symons observed that they might make their science much more attractive if they photographed a great many phenomena and exhibited them in public places, for many people thought that the study of meteorology was the calculation of tables of figures merely, which did not give any results, whereas their science was a most interesting study.

On Regional Magnetic Disturbances in the United Kingdom and in France.—Professor Rücker read a paper containing the results of further work by Professor Thorpe and himself in connection with the magnetic survey of the British Isles. He stated that in last year's report they found two centers of disturbance toward which the magnetic needle was deflected, one of these being in the sea off the west coast of Scotland and the other near Reading. These disturbances have been further examined, and Professor Thorpe finds that the center of disturbance in Scotland is in the sea somewhere south of the Hebrides. The disturbance near Reading is really a little more north, and, indeed, very near Henley. The ridge or line dividing places of east and west disturbance runs from Henley to Chichester. He has since learned that M. Mascart has found the same ridge in France, thus connecting the magnetic surveys of England and France. The causes of magnetic regional disturbance were then discussed. They may be due to either permanently magnetic rocks, or else to magnetic induction produced by the earth's magnetism. The belt of magnetic rock, 100 miles long, 60 miles wide, and 12 miles deep, which forms the principal disturbing source in England will give disturbances exactly of the order observed if we suppose it to be magnetized merely by the earth's magnetism. Moreover, any permanent magnetism would be very irregularly distributed throughout such a large mass of rock. He took twelve miles as the maximum depth, because

below that depth the temperature would be too great for the existence of magnetism.

Professor Mascart (of the French Academy) followed with a paper entitled "Sur les perturbations magnétiques en France." He stated that a survey of the north of France had lately been carried out in considerable detail by M. Moureaux, and that he had found a line towards which the magnet was attracted which appeared to be continuous with that discovered by Professors Rücker and Thorpe, and which entered the channel near Chichester. This line extended into the middle of France, and the disturbances became more intense in the southern parts. (See abstract of M. Moureaux's communication to the French Association in the October JOURNAL.).

In the discussion which followed, Professor Rücker stated, in explanation of M. Mascart's theory, that there was probably a region of magnetic rocks extending from the south of England under the Channel and into the middle of France, which was completely concealed by superposed strata which could themselves produce no effect upon the magnet. If this view were correct, the magnet was thus mapping out the old igneous floor upon which sedimentary rocks rested.

Sir William Thomson asked whether all the disturbing forces would correspond in direction to those produced by the action of the earth; in other words, whether they were due to a north-seeking pole cropping up above the surface. To this Professor Rücker replied in the affirmative.

RAINFALL IN MICHIGAN—NOVEMBER.

The distribution of the rainfall for the state during November is considerably less than that of the preceding month, the average of fifteen years, observation, being 2.93 inches, which amount is general over the entire state, with the exception of the first tier of counties from the south, and the west shore counties of the northern section, which will be noticed by consulting the accompanying chart. The rainfall for this month is not subject to the great fluctuations in amounts as in October, but remains nearer the normal, and in the past fifteen years has not departed much from this normal line.

The largest amount reported at any one station, 6.81 inches, was reported at Niles, in 1881, while the least amount, 0.04

LAKE SUPERIOR
Isle Royal
Houghton
Keweenaw
Luce
Chippewa
Schoolcraft
Mackinac
Baraga
Marquette
Delta
Iron
Menominee
WISCONSIN
Michigan Weather Service.
In Co-operation with the U.S. Signal Service,
Precipitation Chart.
November Normals
13 Years Observations
Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Alcona
Oscoda
Crawford
Kalkaska
Roscommon
Ogemaw
Iosco
Arenac
Bay
Saginaw
Huron
Tuscola
Sanilac
Isabella
Midland
Gratiot
Shiawassee
Genesee
Lapeer
St. Clair
Clinton
Ionia
Oakland
Macomb
Allegan
Barry
Eaton
Ingham
Livingston
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Wayne
Lake Erie
LAKE MICHIGAN
LAKE HURON
Scale of Shades
0 to 1 inches
2 to 3 "
3 to 4 "
4 to 5 "
Over 5 "
INDIANA
OHIO

inches was recorded at Battle Creek, in 1879. In consulting the records, it is found that the heavy or light rainfall does not occur during this month in all portions of the state at the same time, but has been distributed over the entire period of fifteen years, in the different portions of the state. From a selection of ten stations where the records extend from ten to nineteen years, and the stations are well located to show the distribution over the entire state, it is found that the light and heavy rainfall are about equally distributed over the entire number of years, that is, there are six years in 1870–9 in which these stations report a light rainfall, and the same number of years in other portions of the state that report the heaviest rainfall in that period, and in 1880–8 there are four years of each. The lightest rainfall occurring from 1872 to 1875, and the heaviest from 1877 to 1881.

Out of the twenty-two stations from whose records this chart is constructed, there are but five stations which report a rainfall for the month, of less than one inch, and those are situated in the south half of the state.

These records would indicate that although droughts may prevail in the preceding months, yet there will be a sufficient amount of moisture deposited during this month to give all vegetation a fairly good stand. But in this consideration it must not be forgotten that a portion, and sometimes the most of this moisture, will be deposited in the form of snow, and will not moisten up the ground to the same extent as the rainfall would.

It is to be regretted that there have been no records kept in the past which would show the average amount of snowfall during each of the months, and also the amount that lay unmelted on the ground at the close of each of these months, as is now the case. These records would now be of undoubted benefit to all interested in agriculture in showing the average of the past years, so that the lesson could be obtained from the past for comparison with the ones of the present, and the consequent results.

CURRENT NOTES.

TRANSFER OF THE WEATHER SERVICE.—The weather service is transferred from the Military to the Agricultural Department of the Government. After July 1, 1891, it will be entirely under the control of the Secretary of Agriculture. A chief will be

appointed at a salary of $4,500 per year. The present Signal Corps will be discharged from the army and will thereafter serve as civilians.

ABSORPTIVE POWER OF WATER FOR ATMOSPHERIC GASES.*—O. Patterson and K. Sondén have estimated the quantity of oxygen and nitrogen in pure water saturated with air.

Temp. of water scale (?.	Pressure.	N.	O.	Calculated. N.	O.
0.00°	772mm.	19.85	10.15	19.53	10.01
6.	771	16.58	8.39	16.34	8.28
6.32	741	16.20	8.18	16.60	8.39
9.18	729	14.96	7.60	15.58	7.90
13.70	771	14.37	7.24	14.16	7.14
14.10	770	14.35	7.15	14.16	7.05

GLACIAL CLIMATE.—Professor James Geikie, of the University of Edinburgh, has an elaborate essay on the Evolution of Climate in the *Scottish Geographical Magazine* for February, 1890, handsomely illustrated with charts of the world, in which he attempts to indicate the general growth of the continental areas since Palaeozoic time. His thesis is that glacial climate, if dependent on such physical conditions as are presented in Croll's theory, has had no considerable opportunity for development until in Tertiary or Pleistocene time. The continental areas grew large enough to produce extremely glacial conditions at times of maximum orbital eccentricity. A possible exception is noted in favor of Permian time. The essay will well repay reading, especially by those many geologists with whom Croll's theory has been going out of fashion in late years. W. M. D.

HEIGHT OF THE AURORA.—A. Paulsen making measurement at Godthaab gets heights for different auroræ ranging from 0.6 to 67.8 kilometers. Another series of observations made by Garde and Eberlin at Nanortalik, near Cape Farewell, gives values varying from 1.6 to 15.5 kilometers. The results obtained by the Swedish International Expedition at Spitzbergen vary from 0.6 to 29.2 kilometers. "These observations therefore lead to the conclusion that auroræ are by no means confined to the highest parts of our atmosphere, but that they occur almost indifferently at all altitudes. In support of this view Paulsen gives accounts of several appearances of auroræ beneath the

* Journal of the Chemical Society, October, 1890, page 935.

clouds and the summits of mountains. It is interesting to compare the new values with those given by previous observers." . . . Flögel gave as limits 150 to 500 kilometers; Reimann 800 to 900 kilometers; Nordenskiöld a mean height of 200 kilometers; while Lemström has seen auroræ as low as 300 meters, and Hildebrandsson has seen auroræ in a completely clouded sky. Paulsen thinks that in the temperate zone auroræ appear only in higher strata, while in the auroral zone they appear in lower strata of atmosphere.—*Nature*, October 31, 1889.

An Earthquake-Proof Church. — Consul Webb reports from Manilla an attempt to build a church which shall not be injured by the earthquakes which are not rare there. This church is to be made of iron and is to be so firmly bolted together that an earthquake can no more shake it apart or even seriously injure it than it could a solid block of stone. The inventor is Senor Palacios y Guerra, an engineer of considerable local prominence. The church is to be 162 feet long by 70 wide and is to have several towers, two of which will be 170 feet high. The cost will be about $350,000.

The idea involved in this structure is that of an iron structure so firmly bolted together that it can move only as a whole. This is different from the idea advanced by a Chicago architect to the writer, when the latter pointed out the possibility of earthquakes in his city and the consequent danger to the many storied structures which are found desirable at present. The earthquake-proof feature of these structures, it appears, lies in their iron frame work, but the framework, in this case, would yield without serious injury to slight displacements. The structures in Chicago are made on the plan of the basket, while the new Manilla church is on that of an unyielding block.

Rotary Action of Storms.—Readers of the Journal may not have happened to see a curious account of the effect of the great November cyclone of 1888, in the way of sweeping a flight of killdeer plover out to sea from the Carolina coast and landing them on the shores of New England; a striking illustration of the rotary action of storms. While the center of the cyclone was between Hatteras and Block Island, the westerly gales that blew off the southern coast, are supposed to have carried the birds into the cloudy and rainy area of the storm, where they appear to have lost all sense of direction and floated with the

winds; on November 25th and 26th, they were seen in great numbers on the eastern coast of Nantucket and Cape Cod and on the Isles of Shoals, where they are hardly known, especially at this season; they were described as tired, thin and hungry, as if exhausted by a long flight without food or rest; none were seen more than a mile or two inland, showing that they alighted as soon as they could on reaching land. The detailed account of the occurrence is given by Dr. A. P. Chadbourne, in the *Auk*, a quarterly journal of ornithology, for July, 1889, under the title of "An Unusual Flight of Killdeer Plover on the New England Coast." W. M. D.

THE BAROMETER AND FIRE-DAMP EXPLOSIONS.—In a recent article in the London *Morning Post*, Mr. H. Harries of the Meteorological Office, refutes the widespread belief that explosions of fire-damp always occur with a low barometer. According to the writer's statistics three explosions out of every four are marked by anti-cyclonic instead of cyclonic systems of pressure. In dealing with the question of the influence of barometric changes on the state of the gas in mines, it should be remembered that the gas exists under two totally distinct conditions. The waste spaces are so many receptacles for fire-damp where it accumulates in open contact with the atmosphere, and there can be no question that these accumulations respond to every change of pressure, and that, therefore, a low barometer is rather dangerous if these places are not well ventilated. But the amount of gas which escapes from them is small as compared with the amount in the solid coal or in the cavities of the earth where it is retained at an enormous pressure. Admitting that the outer crust of the earth, like a hollow india-rubber ball, has an undulatory movement, sinking and rising with the application and removal of pressure, it will be understood that when the ground sinks under high pressure the coal strata will tend to crack and through the minute fissures thus formed, gas may readily escape into the mine, while the pressure on the pent-up reservoirs, when not far distant from the working faces, would be sufficient to burst all bounds and flood the galleries with gas. As pressure is removed, the strain would decrease and the fissures close up again and so check the flow of gas from the solid coal.

The popular belief agrees very well with the theory which relates to the least dangerous form in which the gas exists, but

as has been shown above it does not apply to the far more important and dangerous form of fire-damp. The subject is one which involves great issues of life and death, and accurate measurements under the supervision of a small committee composed of seismologists, geologists and meteorologists would soon ascertain the facts and deduce laws therefrom.

THE TEMPERATURE OF THE AIR AT DIFFERENT HEIGHTS.—In a work recently received at the library of the New England Meteorological society, Cambridge, Mass., from the author, Mr. Julius Juhlin, on "The Temperature of the Air at Different Heights," he discusses the subject plainly and at great length.

He first treats of it historically, giving the course pursued and the results obtained by J. Six, in 1784 and 1785; Karl Fritsch, in 1855; William Marriott, in 1882-6, and many others; giving in most instances the publications in which the results and details of the observations may be found. Next he describes the thermometers used by him in his own investigations at Upsala, Sweden, in the winter of 1887 and again in 1888; giving in detail the exposure, manner and time of taking the observations, and then the observations in full through January, February and March, 1887, and the same months in 1888. Then he reviews the influence of the sun on the temperature of the air, and finally gives a summary of all the facts obtained and conclusions drawn.

In his summary he says: 1st. The depression of the temperature caused by radiation from the thermometer, is nearly constant at different heights above 0.5m (19.5 inches), above the surface of the snow.

2nd. During the clear nights in winter the temperature increases with the height; this phenomenon begins some two or three hours before sunset and continues from one to two hours after sunrise.

3rd. The increase of temperature with the height is greater in winter than during the other seasons.

4th. The increase of the temperature with the height is a simple function of the temperature, so that the lower the temperature the greater the increase.

5th. During cloudy or foggy winter nights the temperatures at different heights are nearly uniform.

6th. The variation of temperature follows very closely with the variation of cloudiness.

7th. A thin or high cloud appears to prevent and make faint the inversion of temperature with the height.

8th. In winter the surface of the snow is colder than the surrounding air.

9th. The fact that the winter abounding in snow is characterized by strong and severe cold explains very well the physical properties of snow.

10th. The temperature on the hills and at great heights is much higher than on the low lands during the calm winter nights. J. WARREN SMITH.

ANNUAL PERIOD OF THE DIURNAL AMPLITUDE OF THE MAGNETIC DECLINATION.—In this memoir read before the French Association at Limoges, 1890, (Meteorological Section, August 9), Professor D. Ragona, director of the Modena observatory, gives the results of five years observations which he has made on the amplitude of the magnetic declination between 8 A. M. and 2 P. M. The reduction of the observed amplitudes has furnished him with the following formula for the general expression of these amplitudes:

$$\begin{aligned}\text{Mag Ampl.} = 7'.203 &+ 3'.1884 \sin (281^\circ\ 38'\ 59'' + H).\\ &+ 1.4372 \sin (274^\circ\ 28'\ 18'' + 2H).\\ &+ 0.1363 \sin (240^\circ\ 14'\ 27'' + 3H).\end{aligned}$$

The calculated values are very nearly the observed ones. After having formed a table of calculated values he has found, by using second differences, the following epochs for the largest amplitudes (M), the smallest amplitudes (m) and the mean amplitudes (p) of the magnetic declination between 8 A. M. and 2 P. M., the asterisks indicating the chief maximum and the chief minimum:

Magnetic Amplitude.	p	M^*	m	M	p	m^*
Day of Month.....	March 3	April 8	June 25	Sept. 17	Oct. 13	Dec. 29
Day of Year.....	62	98	176	260	286	363

From twenty years, thermometric observations the author has deduced the following dates of the maximum, minimum, and mean temperature at Modena:

Temperature.....	M	p	m	M	p	m
Day of Year.....	93	106	129	217	291	364

There is a close connection between the annual period of the magnetic amplitude and the temperature. Regarding these comparisons it must not be forgotten that in the present calculations the unit is the year, and, consequently, we must always

refer the differences to this unit. Thus a difference of ten days is only $10 \div 365 = 0.027$ of unity.

For the primary phases of the magnetic amplitude we have:

M^*	98	M	93
m^*	363	m	364

For the secondary phases of the magnetic amplitude we have:

Magnetic Amplitude.		Temperature.
m	176	$\frac{1}{2}(129 + 217) = 173$
M	260	$\frac{1}{2}(217 + 291) = 254$

The mean autumn phase is 286 for the magnetic amplitude and 291 for the temperature. The only exception is the mean spring phase (62) which does not coincide with the mean spring phase of the temperature (106) and this forms a special feature of the annual period of the magnetic amplitude.

The author has shown that the two aerial currents from NE and SW have at Modena opposite phases of frequency, that is to say, the epochs of the maximum frequency of the NE currents are those of the minimum frequency of the SW currents and *vice versa*. These are the dates found by the author, placed by the side of those of the magnetic amplitude:

Frequency (F)			Magnetic Amplitude (M)		M-F
NE.	SW.	Date.	Date.		Days.
M	m	107	M	98	−9
m	M	191	m	176	−15
M	m	273	M	260	−13
m	M	373	m	363	−10

Thus the greatest magnetic amplitudes occur (with a few days precedence) at the epochs of greatest frequency of NE winds, and the smallest amplitudes at the epochs of least frequency of NE winds. All these results are important in showing us new relations between magnetic and meteorological phenomena.

Electricity and Meteorology.—The Chief Signal officer, in his annual report for 1889, lately received, sums up an investigation of the highest interest to meteorology. It is the series of observations on atmospheric electricity carried on for the two or three years, ending August, 1888, under the direction of Dr. Mendenhall, now Superintendent of the U. S. Coast and Geodetic Survey. The full report was presented to the National Academy of Sciences, by which it will be published. The fol-

lowing contains the conclusions reached and are given nearly in General Greely's own words.

The primary object of the work was to determine whether observations of atmospheric electricity could be made useful in weather forecasting. Early in the progress of the work the extremely local character of the phenomena exhibited became evident. It was found that instruments similar in every respect, separated by a distance of a few hundred feet, might give very dissimilar indications. The comparison of similar observations at five-minute intervals, extending through several days, at the various stations failed to show any similarity of fluctuations or movement of electric disturbance from one part of the country to another, and the same conclusion must be drawn from the regular observations. It must be said, however, that the number of stations (at no time greater than six), distributed as they were over a wide extent of country, was too small to justify great confidence in this negative result.

The relations between the electrical conditions of the atmosphere and local weather conditions were carefully studied, with the hope that the result might afford assistance in the prediction of local storms, rain, snow, etc., which offer so much difficulty in forecasting by present methods. The well-known electrical activity during such storms was made the subject of special examination, attention being particularly given to the appearance of negative potential in connection with precipitation. The investigation seemed to only increase the range of meteorological conditions under which negative potential might be looked for, and to diminish the definiteness of relation between it and precipitation. An examination of nearly one thousand cases showed that in about 53 per cent. negative electricity preceded precipitation, the time varying from a few minutes to more than ten hours, while in 47 per cent. no negative potential was observed. This result is in accord with the continuous photographic record at Baltimore when the latter is subjected to analysis. The examination of about two thousand cases at the Kew observatory, covering a period of about eight years, gives a similar result.

In addition to the fact thus proved, that precipitation was not generally preceded by negative electricity, the observations showed that negative potential was often recorded when there was absolutely no precipitation at the point of observation. In many cases, in fact, it was observed when the sky was perfectly

clear. In a considerable number of cases it was found that precipitation had occurred within a radius of two hundred miles, but in many cases nothing of the kind took place, and it appears to be abundantly proved that negative electricity may be observed without being in any way related to precipitation, past, present, or future, and that it may be due to other causes, many of which are extremely local in their character.

Taking all the facts into consideration, it seems to be proved that the electrical phenomena of the atmosphere are generally local in their character. They do not promise, therefore, to be useful in weather forecasting, although a close distribution of a large number of observers over a comparatively small area would be useful in removing any doubts which may still exist as to this question. Unfortunately, the work requires observers of more than usual skill and intelligence, and the equipment of a station is somewhat expensive. The restrictions to which the work of the Signal Service is necessarily subjected, forbid the further extension of an investigation which appears to promise so little in the way of practical returns.

PUBLICATIONS RECEIVED.

[Our correspondents will kindly take acknowledgment in this list as an acknowledgment of their courtesy in sending us the publications mentioned. In so far as we can find space the publications mentioned here will be noticed more at length in other parts of the JOURNAL.—EDITORS].

"Bulletin of the N. E. Met. Society," No. 69, July, 1890. Gr. octavo, 8 pages.

"Missouri Weather Service." July, 1890. Octavo, 4 pages, with map of precipitation.

"Monthly Review of the Iowa Weather and Crop Service." July, 1890, volume 1, No. 4.

"On the Cheapest Form of Light." S. P. Langley and F. W. Very. Octavo, seventeen pages, three plates. Reprint from the *American Journal of Science.*

"Ciel et Terre." August 16, 1890. Octavo, twenty-four pages. This number contains an article by P. J. de Ridder and C. Buvé on the influence of cultivation on untimely frosts.

"R. Osservatorie di Palermo; Dr. Riccó, Director; Bollettine Met., No. 5, Maggio, 1890." Quarto sheet.

"State Board of Health of Tennessee; Bulletin." August 20, 1890; Vol. VI, No. 1. Octavo, sixteen pages.

"Uebersicht uber die Witterungverhältnisse in Königreich Bayern, während der Juni, 1890." Single sheet.

"Journal d'Hygiène et Climatologie." Weekly, twelve quarto pages. Published by Dr. Prosper de Pietra Santa, Paris.

"New York Meteorological Observatory." July, 1890. Large octavo, eight pages. Dr. D. Draper, director, Central Park, N.Y.

"Census Bulletins." Number 8, relates to mines and mining; slate. Number 10 relates to quicksilver. Octavo, ten pages each.

"Mississippi Weather Service; Bulletin 46." Double sheet, July, 1890. R. B. Fulton, director, central office, University, Miss.

"Bollettino mensuale pubblicato per cura dell'Osservatorio centrale in Moncalieri." Second series, volume ten, number seven; July, 1890.

"Rapport Annuel de l'Observatoire de Paris pour l'année, 1889," par M. le Contre-Amiral Monchez, directeur. Paris, 1890. Gr. octavo, 27 pages.

"Nebraska Weather Service." G. D. Swezey, Director, G. A. Loveland, Assistant. Weather and Crop Bulletin for June, 1890. Four octavo pages and rainfall map.

"Report of the Superintendent of the U. S. Naval Observatory for the year ending June 30, 1889." Reprint from the report of the Secretary of the Navy, pp. 414–425.

"Memorias de la Sociedad Cientifica Antonio Alzate." Vol. III, Nos. 9 and 10, March and April, 1890, Mexico. Octavo, 96 pages. Among other articles it contains a project for draining

lakes Tezcuco, Chalco and San Cristóbal, by Sr. Alzate; the city of Puebla, from a sanitary point of view by Sr. Covarrubias; and a report on earthquakes.

"Nebraska Weather Service Bulletin and Crop Report." July, 1890. Octavo, four pages, and rainfall map. Boswell Observatory, Doane College.

"Die Strahlung der Sonne; eine physicalische Studie." By Joseph Brucker. Octavo, unbound, eighty-nine pages. Published at Medford, Wisconsin.

"Meteorological Service; Dominion of Canada; Monthly Weather Review." May, 1890. Quarto, ten pages. Charles Carpmael, director; office at Toronto.

"Michigan Crop Report," No. 106, August 1, 1890, and 42nd Monthly Report of the Mich. Weather Service. Published by the Secretary of State. Octavo, 22 pages, 2 maps.

"Himmel und Erde," August, 1890, Vol. II, Number 11. This number is chiefly astronomical, but contains a popular article on oceanic volcanic eruptions and water-waves by Dr. Rottok.

"Meteorologische Zeitschrift, herausgegeben im Auftrage der oest, Gesellschaft für Met. under Deutschen Met. Gesellschaft, redigirt von Dr. Hann und Dr. Köppen." Seventh year, eighth number; August, 1890.

"Jahrbücher der k. k. Central-anstalt fur Meteorologie und Erdmagnetismus; Officielle Publication." 1888. Vienna, 1889. Quarto, 411 pages. Publication of the Austrian Weather Service. Dr. Julius Hann, director. The best model for the international form.

"Bulletin mensuel de l'Observatoire magn. et met. de Zi-ka-wei, (near Shanghai, China), fondé et dirigé par les Missionaires de la Compagne de Jésus; avec une étude sur les orages de Kiang-nan en 1889." Vol. XV., year 1890. Printed at the Mission. Quarto, 243 pages, 22 plates. The observatory is in

lat. 31° 12′ N, long. 121° 26′ E, altitude 23 feet. Rev. S. Chevalier, S. J., is now director.

"Monthly Report of the Kansas State Board of Agriculture." July, 1890. Octavo, forty-one pages. M. Mohler, secretary, Topeka, Kansas. This contains reports of the Kansas Weather Service, with a rainfall map.

"Pennsylvania Weather Service; Monthly Weather Review." July, 1890. Octavo, four pages, tables and map. These reviews are prepared under the direction of the committee on meteorology of the Franklin Institute.

"Il Rosario e la Nuova Pompei; Periodico Mensuale." Volume seven, number four; June, 1890. This journal contains reports from the observatory at Pompei and devoted to meteorological, geodynamical and vulcanological studies.

"University of Illinois; Agricultural Experiment Station; Bulletin No. 10." Also, "Bulletin No. 11." Champaign; August, 1890. Octavo, pages 329–352. The first relates to investigations of milk tests, the second to the growth of wheat.

"Mémoirs de la Société des Naturalistes de Kiew." Volume ten, part three; and volume eleven, part one, Kiev, 1890. Octavo; pages 88 and 259. The latter contains an article by M. Koudritzki on new data on the question of the influence of forests on climate.

"Symons's Monthly Meteorological Magazine." August, 1890. It contains: The Great Rain of July 17, 1890, with map; Phenological Observations; Ball Lightning; Met. Station at Pompei; Cause of Atm. Depression; Cold Weather of March; and several reviews.

"Reports of the Consuls of the U. S., No. 116," May, 1890, Washington. Issued by the Bureau of Statistics, Department of State. Octavo, 191 pages. Of much commercial interest, with occasional geographical and meteorological information. Of the latter are the reports on Barcelona, Venezuela; on the agricultural condition of European Russia; on Norfolk Island; and on the South African districts.

"Revista do Observatorio; Publicacao mensal do Observatorio do Rio de Janeiro." June and July, 1890. Large octavo, sixteen pages. It contains an account of the Meteorological Congress at Paris, and of the subsidies of Matto-Grosso for geography and climatology.

"Pilot Chart of the North Atlantic Ocean." September, 1890. Besides the usual information, it gives a map of surface temperature between 40° and 50° of north latitude, eastward from the American coast. Published by the Hydrographic office, U. S. N., Capt. Henry F. Picking, Hydrographer.

"Apuntes relativos á algunos Observatorios é Institutos meteorológicos de Europa." By Rafael Aguilar Santillán. Octavo, thirty-seven pages, Mexico, 1889. This is the result of the observations of the author on a visit to the French, Belgian, Italian, Austrian, German and Spanish meteorological services.

"Forschungen auf dem Gebiete der Agrikulturphysik." Volume XIII, parts three and four. Octavo, 188 pages. Published at Heidelberg, by Professor Dr. E. Wollny. It contains an article (forty pages) by Dr. Wollny, on the relation of precipitation to vegetation and soil; the penetration of rain into the soil.

"Washington Observations, 1885; Appendix I; International Astrophotographic Congress," by Lieut. A. G. Winterhalter, U. S. N. Bound; quarto; pages xvi + 354. It includes, also, accounts of many observations and other scientific institutions visited by the author.

"Appendix II; Saturn and its Rings," by Professor A. Hall. Quarto; twenty-two pages and three full-page cuts of Saturn.

"General Weather Service of the United States; Monthly Weather Review." June, 1890. Quarto, twenty-seven pages, three maps. Prepared under the direction of General Greely, by Captain Dunwoody. It contains, besides the usual summaries, the monthly rainfall and temperature at New Ulm, Texas, for eighteen years, by C. Runge; monthly temperature and precipitation at Washington, Arkansas, 1840 to 1861, and

1888 and 1889; precipitation and temperature at Forsyth, Georgia, since 1874, by Thomas G. Scott.

"Boletin mensual." Volume two, number ten; October, 1889. Quarto; pages 237–264. This journal contains elaborate reports of observation and their analysis for the Mexican republic; also bibliographical notes and discussions of the climate and productions of the country. It is issued from the national observatory at Tacubaya.

"Ohio Meteorological Bureau; Seventh Annual Report." 1889. Octavo, 218 pages. The board of directors consists of Prof. B. F. Thomas, president; C. R. Kilbourne, secretary; L. N. Bonham, and Geo. H. Twiss; C. M. Strong is the signal service assistant. This volume contains the monthly summaries and many phenological and other observations.

"Das Wetter." August, 1890. Octavo, twenty-four pages. Edited by Dr. Assmann. This number contains: Weather predictions by Dr. Lang; the Climates of the German "Schutzgebiete," by Dr. Wagner (continued); Number of dust particles in the atmosphere, by Dr. Andries; causes of cyclones on tke North Atlantic, by H. Habenicht; evaporimeter by H. Dufour; and many other meteorological notices.

"U. S. Scientific Expedition to West Africa, 1889." David P. Todd, director. This expedition published bulletins of scientific interest while on the way. The following are of interest to meteorologists. No. 2—Meteorological. This gives the plan of meteorological work by Professor Abbe. No. 6—Water-spouts. Four octavo pages printed on the U. S. S. *Pensacola*, as were also the others mentioned here. This is a general report on the spouts observed by Professor Abbe. No. 11—Terrestrial Physics. Four octavo pages, by E. D. Preston. Instructions for observing. No. 13—Localities of Scientific Interest on St. Helena. Four octavo pages, by Professor Abbe. An account of sixteen stations (No. 3 is to be crossed out), with a list of thirteen rainfall stations.

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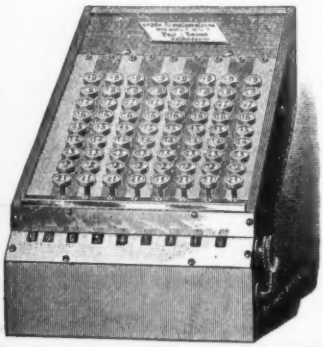

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